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(54) APPARATUS FOR CHECKING TAPER

(71) I, MARIO POSSATI, trading as FINIKE ITALIANA MARPOSS Soc. In Accomandita Semplice di Mario Possati & C., an Italian Citizen of Via Saliceto, 13 - 40010 S. Marino - Bentivoglio, (BO), Italy, do hereby declare the invention for which I pray that a Patent may be granted to me, and the method by which it is to be performed to be particularly described in and by the following statement:-

The present invention relates to an apparatus for checking the taper of the tapered surface of a workpiece with first and second reference means adapted to cooperate with the tapered surface at respective positions along it of different diameters and with measuring means adapted to provide indications responsive to the position of the first and second reference means.

The known apparatuses for measuring the taper of internal surfaces generally comprise a case, which also has a taper shape, wherein two pairs of radially movable sensing contacts are arranged, and placed on two transversal planes at a known distance apart. The contacts of each pair are diametrally opposite with respect to the case axis and they touch the surface to be measured at points which are substantially opposite with respect to the surface axis. Each of the contacts is connected to an associated measuring head, or each pair is connected to a respective measuring head.

The taper value is obtained by processing the signals supplied by the measuring heads.

The gauges of this type are unusable when the diameter of the cross section of the taper surface in the measurement planes is smaller than a certain value, approx. 10 mm. and such gauges are least of all usable when the taper surface is at the end of a long cylinder bore.

The reason is that the dimensions of the fingers which connect the sensing contacts to the arm-sets of the measuring heads cannot fall below certain values, and too long fingers would be subject to deformations by bending stress and so provide unreliable measurement values.

This situation will take place, for example, when measuring the taper of the end surface of an injector body of a Diesel engine; the internal surface of a typical injector body comprises a cylindrical part with a diameter of 3mm., said cylindrical part finishing with a truncated cone part about 2mm. deep, with a smaller diameter of 1mm., and at a distance of about 40mm. from the body end face.

It is also known to manually measure the taper of surfaces of this type at a bench, by clamping the workpiece to a bracket so that the axis of the taper surface is perpendicular to a bracket reference plane, then a samll sphere of a suitable diameter is inserted until it rests on the taper surface, then by means of a gauge the penetration depth is measured; thereafter this operation is repeated by using a sphere of a different diameter. According to the radius of the spheres and depending on the penetration depths, it will be possible to calculate the taper value.

This measuring procedure, apart from requiring considerable time, should be performed by a skilled operator; thus it is rather expensive if it has to be repeated for several workpieces, for example, in order to select them.

An object of the present invention is to provide an apparatus for the measurement of taper which measures very rapidly, supplies a direct indication of the taper, may be used by non-skilled operators and is rugged, accurate and inexpensive.

Another object is to provide an apparatus for the measurement of taper that is suitable to gauge the taper of internal surfaces whose transversel sections have very small diameters, less than 10mm., or which are distant from the workpiece face, because, for example, they are at the end of a bore.

According to the invention, there is provided a gauge apparatus for checking the taper of a conically tapered surface of a workpiece, comprising:

support means;

first mechanical reference means for contacting the tapered surface around a first circumference thereof lying in a plane perpendicular to the cone axis of the tapered surface, the circular cross-section of the tapered surface in said plane having a pre-set diameter;

second mechanical reference means for contacting the tapered surface around a second circumference thereof lying in a second plane perpendicular to the cone axis of the tapered surface, the circular cross-section of the tapered surface in said second plane having a second different pre-set diameter;

first connection means mounted on said support means and carrying said first mechanical reference means, the first connection means being arranged to permit displacements of the first mechanical reference means relatively to the support means along a gauge axis of the apparatus with which axis the cone axis of the workpiece is at least approximately aligned during checking of its taper;

second connection means mounted on said support means and carrying the second mechanical reference means, one of the first and second connection means being movable with respect to the support means to permit displacements of the respective mechanical reference means in a plane substantially perpendicular to said gauge axis; and

measuring means coupled to said support means and to said first connection means for providing a measurement signal responsive to said displacements along said gauge axis.

One arrangement according to the invention will now be described in further detail by way of example with reference to the accompanying drawings, in which:-

Fig. 1 is a side view partially in section, of a preferred embodiment of an apparatus for measuring the taper of internal tapered surfaces;

Fig. 2 is a longitudinal enlarged section of part of the apparatus of Fig. 1.

Referring to Fig. 1, the apparatus comprises a support 10 which carries a body 12. The body 12 has a recess 14 wherein a measuring head 16 is located. Head 16 has a protection and support shell 18, having substantially a cylindrical shape, housed with slight play within recess 14. Within the shell there is contained a measurement transducer 20 of the differential transformer type formed by electric windings 22 fixed to shell 18 and by a movable set comprising a core 24 carried by shaft 26. Shaft 26 slides within two bushings 28, 30 fixed to shell 18; the shaft protrudes from ne end of the shell passing through a drilled plate 32 and an elastic seal-tight gasket 34.

Shaft 26 is urged outward by a spring 36 placed between bushing 28 and a stop 38 fixed to the shaft; a stop ring 40 mounted at the internal end of the shaft restricts the movement caused by spring 36.

The windings 22 are connected to an electric power supply in processing and indication unit 42 by means of conductors 44 which emerge from shell 18 by passing through a hole 46. The second end of the shell 18 is closed by a cover 48; the end part of the shell is threaded externally and is matched to a bushing 50 which has a threaded recess 52.

A fork plate 54 is inserted within a groove 56 provided in bushing 50 and its ends 58 are fixed to support 10; the cylindrical external surface of the terminal part 60 of bushing 50 is knurled so it can be easily handturned.

In the upper part of body 12 there is a threaded hole 62 wherein a dowel 64 is screwed; the end of the dowel penetrates into a longitudinal groove 66 provided in shell 18. A spring wire 68 is welded to the external end of shaft 26, so that the wire is aligned with the shaft; a spherical body 70 is welded to the free end of wire 68. The section of wire 68 is such that the wire is flexible but inextensible.

a plate 72 with a central bore 74 is fixed to body 12; a tube 76 coaxial with the wire 68 is welded to plate 72 around hole 74 and a part spherical body 78 is welded to the tube end; body 78 has a hole 80 aligned to the tube.

The diameters of the bores 74 and 80, just like the inside diameter of tube 76, are substantially the same and only slightly larger than the diameter of the spherical body 70.

As may be seen in the drawings, wire 68 is internal and coaxial with respect to tube 76 and the spherical body 70 projects out of the part spherical body 78; for each relative position of the two spherical bodies there is a definite taper surface which is tangential to both the bodies.

A workpiece 90, consisting of an injector body for Diesel engines, is shown in the measuring position.

To save space, the injector body has not been shown in its full length; the distance between the front surface 92 and the end taper surface 94 to be checked is considerably longer than it appears to be in the figures, and this also applies to the length of tube 76 and of wire 68.

Fig. 2 shows the measuring principle : the bodies 70 and 78 are both in cotnact with the truncated cone surface 94 of the workpiece 90, around respective circumferences.

The radii of the spherical surfaces of bodies 70, 78 are r and R respectively, and the distance between centers B, C of the two bodies is h; the distance of center B from apex D of the taper surface 94 is a; E and F

are two contact points of the surfaces of the two bodies with surface 94 in a longitudinal section plane.

As the angle DÊB of triangle DEB is a right angle, and if the angle BDE of the same triangle is α, we have: $\sin\alpha = r / a$ (1)

As the triangles DEB and DFC are similar, it is possible to write this proportion between the corresponding sides:
$a / r = (a + h) / R$ from which, by obtaining a :
$a = h r / (R - r)$ and by substituting the value of a in (1) : $\sin \alpha = (R - r) / h$ (2)

Thus, $\sin \alpha$ is inversely proportional to distance h; if h is determined it is obvious that the value of the angle 2α at the vertex of the taper surface may easily be obtained.

The operation of the gauge is as follows : in the absence of workpieces to be checked, spring 36 urges the shaft 26 outward (to the right in Fig. 1) till stop ring 40 touches bushing 28; thus the spherical body 70 reaches its limit position in which it protrudes to the farthest extent beyond the spherical body 78. The two bodies 70, 78 define a taper surface tangential to both; as the distance h between the centers of the bodies is then the maximum that can be reached, for pre-established fixed values of R, r this position represents the minimum angle 2α at the vertex of the taper surface which can be measured.

By applying pressure on the spherical body 70 in the direction of the axis of tube 76, shaft 26 is pushed to inward (towards the left in the figure) till spring 36 is totally compressed; consequently the spherical body 70 reaches the limit position in which it is closest to spherical body 78. Distance h between the centers of the bodies is now the minimum that can be reached and the angle 2α at the vertex of the taper surface is the widest that can be measured with the pre-established values of R and r.

The values of r and R and thus the nominal value of h are chosen depending on the nominal value of the angle 2α to be measured and on the diameter of the two cross sections of the taper surface at which it is desired that contact with the two spherical bodies shall take place.

It is advisable that the values of r and R be such that for the nominal angle 2α the value of h is intermediate betwen the two limit values mentioned above. Once these values have been chosen it is possible to proceed with the manufacture and assembly of the various elements (spherical bodies, wire, tube . . .).

For example, to measure the taper of surface 94 of an injector body whose vertex angle 2α has the nominal value of 60°, a gauge has been manufactured in which the values of r and R are respectively 1.5 and 3 mm, distance h, for a nominal taper, is 1.5 mm, the diameter of bore 80 is 2 mm, the diameter of wire 68 is 0,6 mm and the length of the wire is 50 mm.

After the fixing of tube 76 to body 12, the head 16, to whose shaft 26 the wire 68 with its spherical body 70 is already welded, is inserted in recess 14; dowel 64 is then screwed in so that its end enters groove 66 in such a way as to prevent rotation of head 16 while leaving it free to slide in a longitudinal direction.

Head 16 is inserted till body 70 protrudes from bore 80, and then bushing 50 is screwed inward on the end of shell 18 and the fork plate 54 is inserted in groove 56 and fixed to support 10.

The gauge may be operated either in a manual or in an automatic way; in the first case workpiece 90 is picked up by the operator and pushed into the measuring position, shown in Fig. 1.

If the pressure that the operator applies to the workpiece is substantially in the direction of the tube 76 axis, the workpiece will automatically settle so that the contact between the spherical body 78 and surface 94 occurs around a circumference. At the same time the spherical body 70 is pressed by the workpiece and pushed towards body 78; the force that is applied to body 70 must be sufficient to overcome the thrust of spring 36.

The dimensions of spring 36 and those of the steel wire 68 are chosen so that the force necessary to compress the spring is considerably smaller than the force required to bend the wire. Therefore there is the certainty that the wire remains substantially straight when measurement is taken.

In order to zero set the gauge, a master workpiece is pushed onto tube 76 and kept pressed so that the taper surface 94 contacts the body 78 around a circumference.

By rotating bushing 50 it is possible to move head 16 forward or backward till it takes up a position like the one shown in Fig. 1, when core 24 is in a substantially central position with respect to windings 22 and thus the value of the output signal of the transducer is zero or very close to zero.

Bushing 50 cannot move in the direction of shaft 26, therefore its rotation causes movement of shell 18, which is unable to rotate since dowel 64 is inserted in groove 66, along the direction of shaft 26. Indication that a position such as is shown in Fig. 1 has been reached is displayed by a readout meter comprised in unit 42; when the needle is in the central zero position turning of bushing 50 is stopped and dowel 64 is screwed in until it clamps the shell 18 with respect to body 12.

The accuracy that is obtained by movement of the shell in this way is not too precise; a fine zero setting is effected electrically by using potentiometers which have control knobs placed beside the readout meter of

unit 42.

Now the gauge is ready to measure the workpieces; this operation consists in pushing the injector body onto tube 76 till the end taper surface 94 meets body 70, pushes it towards body 78 and rests against body 78. The value of the signal supplied by transducer 20 is proportional to the difference of the present distance between the centres of bodies 70, 78 and the corresponding distance when the master workpiece was applied.

The signal phase, which determines the direction of movement of the meter needle to one or the other side from the central zero position, indicates that the vertex angle of the taper surface is bigger or smaller than the nominal angle, and it depends on the fact that body 70, and thus also core 24, is shifted from its nominal position towards one or the other of the two limit positions above stated.

On the meter scale the values of vertex angle 2α can be directly displayed, instead of the sin α values. Of course, in this case the meter scale or the meter drive are not linear.

In the manufactured gauge, having the values of r, R and the nominal value of h previously indicated and with a nominal vertex angle of 60°, the sensitivity is approx 12′ of the angle per 5 microns of variation of distance h, and since the axial displacement accuracy of head 16 can be within 0.3 to 0.4 microns, it is possible to detect taper errors of 1′ approx. Connection of the spherical body 70 to shaft 26 by means of a steel wire 68 enables the center of body 70 to perform small movements substantially in a plane perpendicular to the axis of tube 76 up to the amount permitted by the radial play of wire 68 or of body 70 with respect to tube 76 or body 78.

This characteristic is very important as it avoids positioning problems and will always guarantee measurement accuracy. In fact, were body 70 unable to move transversely of the axis of tube 76, as would happen if connection wire 68 were rigid, but were only able to move in the direction of the axis, a correct measurement woul only be obtained if the axis of the tapered surface 94 were exactly aligned with the tube axis. With the body 70 able to move laterally, the centers of the two bodies 70, 78 are always located on the axis of the taper surface, even if the workpiece is slightly misaligned with the axis of the tube 76. Therefore, the contact between the same bodies and the taper surface still occurs around two respective circumferences and the geometric relationships discussed before with reference to Fig. 2 remain valid.

If the mounting of the body 70 were rigid, and the axis of the taper surface were misaligned with the tube axis due to inaccurate positioning of the workpiece, only one of the two centers of bodies 70, 78 would lie on the taper surface axis; therefore the surface of the other body whose center did not lie on the taper surface axis would contact the taper surface at a single point instead of around a circumference and thus the geometric relationship discussed above would no-longer be valid and the measurement would be unreliable.

It is clear that the use of a wire 68 which is resilient in the transverse direction will ensure considerable time and cost saving, both in the case of measurements carried out in a completely automatic way, because absolute positioning accuracy is not required, and also in the case of measurements carried out manually, because it is not necessary to employ a highly skilled operator.

The possible moving of body 70 away from the tube 76 axis and the bending of wire 68 do not cause significant measurement errors, as has been experimentally proved, because the consequent axial displacements are of an order of magnitude smaller than the radial displacements which caused them.

The measurement operation may easily be automated by providing the apparatus with a device which picks up the workpieces from a loader, urges them towards the apparatus and, after the measurement has been taken, deposits them in an outlet shute. The device carrying the workpieces and urging them towards the apparatus will float, in order to ensure that each workpiece can settle itself with respect to the part spherical body 78 and in this manner guarantee that contact between the latter and the taper surface 94 occurs around a circumference.

As a variant, a floating connection may be utilized between the shell 12 and the support 10.

A possible modification of the apparatus consists in utilizing a rigid shaft instead of flexible wire 68 and in mounting the spherical body 70 so that the center of body 70 may move transversely in a plane perpendicular to the shaft axis. This mounting may be effected by fixing a small disk at the end of the rigid shaft, with the disk faces perpendicular to the shaft axis, and inserting the disk into a suitable (disk-shaped) recess in the spherical body; the recess radius will be greater than the disk radius, so that there is play between the peripheral surface of the disk and that of the recess.

The spherical body may then settle with respect to the taper surface 94, by moving transversely by sliding of the body recess faces with respect to those of the disk; on the other hand, the spherical body fully transmits axial displacements to the rigid shaft.

Another mounting may be affected by rigidly fixing spherical body 70 to a short axial pin and by coupling the other end of the pin to the rigid shaft end through a spherical joint which allows the pin, and also the body

70, to make universal angular movements on the shaft end.

With this structure too body 70 transmits the axial movements to the shaft, but remains free to settle itself with respect to the taper surface 94 by effecting transverse displacements as permitted by the spherical joint.

The unit 42 can include circuits which, depending on the value of each measurement, control output devices that separate the workpieces into different categories.

According to a further possible modification, the spherical body 70 is stationary being coupled to support 10 and the body 78 can move axially being coupled to the moving set of the measuring head. In this case the tapered surface 94 rests on stationary body 70, pushing body 78 and moving it away from body 70. The measurement signal has the same value and therefore unit 42 need not be modified.

The apparatus may be modified for checking external taper surfaces. For this purpose bodies 70, 78 are replaced by elements defining two surfaces of revolution coaxial with each other and tangential to the tapered surface to be checked.

For example, it is possible to employ two groups of spherical contacts the first group being arranged inside tube 76 and the second arranged around a hollow member coupled to the end of wire 68, the length of wire 68 will be such that the second group of contacts cooperates with a section of the tapered surface having diameter 2r while the first group cooperates with a section having diameter 2R ($r < R$).

There may be three contacts in each group equiangularly spaced at 120° from one another.

WHAT I CLAIM IS:-

1. A gauge apparatus for checking the taper of a conically tapered surface of a workpiece, comprising:

support means;

first mechanical reference means for contacting the tapered surface around a first circumference thereof lying in a plane perpendicular to the cone axis of the tapered surface, the circular cross-section of the tapered surface in said plane having a pre-set diameter;

second mechanical reference means for contacting the tapered surface around a second circumference thereof lying in a second plane perpendicular to the cone axis of the tapered surface, the circular cross-section of the tapered surface in said second plane having a second different pre-set diameter;

first connection means mounted on said support means and carrying said first mechanical reference means, the first connection means being arranged to permit displacements of the first mechanical reference means relatively to the support means along a gauge axis of the apparatus with which axis the cone axis of the workpiece is at least approximately aligned during checking of its taper;

second connection means mounted on said support means and carrying the second mechanical reference means, one of the first and second connection means being movable with respect to the support means to permit displacements of the respective mechanical reference means in a plane substantially perpendicular to said gauge axis; and

measuring means coupled to said support means and to said first connection means for providing a measurement signal responsive to said displacements along said gauge axis.

2. An apparatus according to claim 1, wherein said measuring means comprises a measuring head including a measuring transducer, the measuring transducer comprising means fixed to said support and co-operating means moving along the gauge axis with said first mechanical reference means, the apparatus further including processing and indicating means receiving the signals provided by the transducer.

3. An apparatus according to claim 1 or claim 2, wherein said first connection means comprise a resiliently flexible metal wire extending generally along the gauge axis and mounted on the support means for movement endwise along said gauge axis, said wire carrying at one end the first reference means.

4. An apparatus according to any one of claims 1 to 3, wherein said second connection means includes a substantially cylindrical tubular rigid member extending along the gauge axis and having one end mounted on the support and the other end carrying said second reference means.

5. An apparatus according to claim 4, wherein said first reference means comprises a first spherical body, and said second reference means comprises a second part-spherical body of a different diameter through which is a hole coaxial with the gauge axis and the axis of said tubular member.

6. An apparatus according to claims 3 and 5, wherein said tubular member surrounds the flexible wire, the flexible wire being movable along the axis of said tubular member.

7. An apparatus according to claim 3, or claims 3 and 4, or claims 3 and 5, or claim 6, wherein said displacements in a plane substantially perpendicular to the gauge axis occur by bending of the flexible wire.

8. An apparatus according to claim 2, or claim 2 and any one of claims 3 to 7, further comprising adjusting means for adjusting the position of the measuring head along the gauge axis.

9. An apparatus according to claim 5 or claim 6, or claim 5 and either of claims 7 and

8. for checking the taper of the body of an injector for diesel engines, wherein said spherical bodies have diameters permitting the bodies to contact the tapered surface of the injector body around circumferences of said surface that are spaced along the cone axis of the tapered surface, the tubular member and the first connection means having lengths permitting the insertion of the spherical bodies into the bore of the injector body for contacting the tapered surface.

10. An apparatus for checking the taper of a tapered surface of a workpiece, substantially as described with reference to the accompanying drawings.

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1583451 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

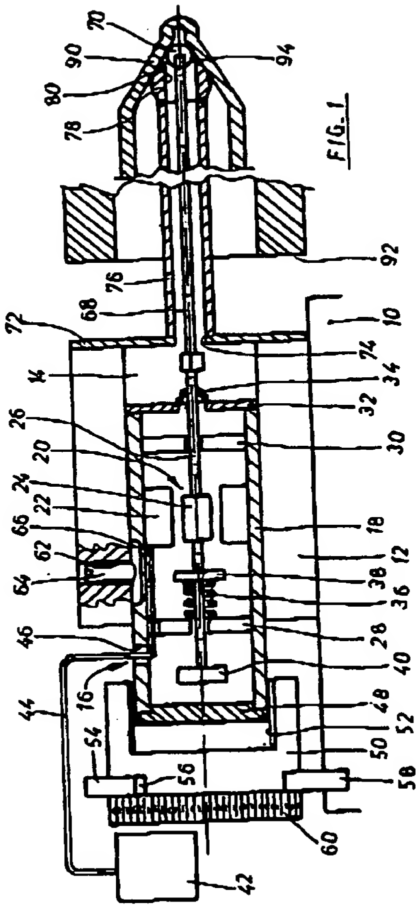

FIG. 1

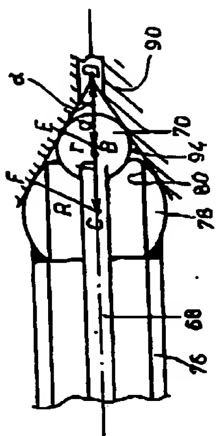

FIG. 2